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# CONTINUING EDUCATION THROUGH COMPUTER-AIDED INSTRUCTION

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## Abstract

Computer-aided and managed instruction has been incorporated into the continuing education program in the Electronics Division of the Los Alamos National Laboratory. Two Control Data Corporation PLATO terminals have been installed in the learning center and have been providing individualized instruction to the employees for approximately 2 years. Reactions from users and total usage figures indicate that there are unique advantages to computer-aided instruction.

User interaction with a computer assures individual response from a student. The learner must be actively involved in the course and cannot passively allow content to flow by. Complex simulations can be programmed and used in the learning process. Thus expensive equipment can be spared the wear and tear attributed to learners.

The breadth of course topics included in the on-line library assures that PLATO has a continuing education offering for most employees. New lessons appear on line at the rate of three or four per week, which helps to certify PLATO cost effectiveness.

Comparisons of courses taken on the terminal to the same or similar courses offered elsewhere indicate that PLATO is advantageous. Computer-aided instruction is available when the learner is ready for initial instruction and later for reviews.

At Los Alamos, the demand for PLATO service is growing. The Laboratory will have eight terminals installed and operating by April 1981.

## Introduction

Continuing education for scientists and engineers is a many-faceted problem. Educators have attempted to solve these problems through a variety of delivery systems. From programmed learning materials through live technical seminars much development has taken place.

In the Electronics (E) Division of the Los Alamos National Laboratory, training specialists have faced the typical problems of educational delivery in the work environment. Finding a block of time suitable to the schedule of a group of employees is typically a problem. Matching the educational level or background of prospective students presents difficulties. Issues include finding an appropriate classroom, the availability of qualified teachers, and the uncertainty of outcomes of the classes.

At the Laboratory, as elsewhere, these enigmas were attacked from a myriad of approaches. In-house classes taught by Laboratory staff, the expert

from out of town, slide tape presentations, videotaped courses, seminars, travel for training, and packaged programmed instruction all have focused on limited aspects of the problem. Each of these delivery systems are currently utilized by the E-Division training staff. Computerized instruction is the new addition to the educational system.

If you view computer-aided instruction as merely automated page turning of programmed instruction, experiment with the PLATO system. PLATO (Programmed Logic for Automated Teaching Operations), developed by the University of Illinois and Control Data Corporation (CDC), was aptly named.

The writings of Plato, the best known philospher of ancient Greece, are inherent in endless numbers of moral, religious, and political doctrines. Plato's works appear in the form of dialogues in which Socrates is the leading character. His doctrines are presented in the Socratic method of reason by question and answer. CDC's PLATO system is capable of replicating this question-and-answer method and much more.

User interaction differentiates computer-aided instruction from audio-visual educational systems. With features like 20 h/day access, interterminal communications, and 0.2-s response time, PLATO is clearly the most complete instructional computer system available today.

## History

Historically, PLATO has its roots in the Computer Education Research Laboratory (CERL) at the University of Illinois. Under the direction of Dr. Donald Bitzer, a research project was initiated to investigate the use of a computer to assist in the teaching process. From its inception in 1959, PLATO has grown into an international system marketed by CDC.

Since the joint program with the University of Illinois began in 1967, CDC has provided increased impetus in development of this first, large-scale, computer-based educational system. A special language, TUTOR, originated by Paul Tenczar, University of Illinois, has evolved as the author language. Concurrent improvements to the computer, to the design of auxiliary equipment, and to the author language and courseware has assured a well-designed, effective computer-aided instructional network.

PLATO combines an advanced Cyber mainframe with an extended core memory to produce a reaction time to student stimulus of less than 0.2 s. A special operating software system combined with the NOS system offers unique capability in authoring courses; each user is a potential courseware author.

Additional features include a computer-driven talk function and a copy device capable of reproducing a hard copy of any display. Other compatible devices under development include a microprocessor-controlled oscilloscope, a video disk player, and a music synthesizer.

PLATO is an educational delivery and management system capable of assessing students, routing them to appropriate learning activities, and providing valuable feedback to the student. The system also maintains a complete data base on all activities.

PLATO features include:

On-line course library
Thousands of hours of courseware
On-line consultants
On-line terminal talk with other users
On-line monitoring capability
Multilingual capability
Electronic mail
Public notes
Student-instructor note files
Term comment-user feedback to author

The computer can also manage the instructional process, including the management of existing courseware such as videotapes and other audio-visual courses. The service is offered in three distinct ways. E Division accesses PLATO through a subscription service. Terminals are installed in the Laboratory facilities with communication links to CDC, Albuquerque, and subsequently to Minneapolis. Another method of acquiring this service includes the purchase of an entire computer mainframe with associated hardware, terminals, and courseware. A third method is a chain of learning centers located in major metropolitan areas.

Four CDC computers located in Arden Hills provide PLATO service to industry, educational institutions, and governmental agencies across the United States. The Laboratory terminals are on the MINN-C system, which serves installations in the 10-state area including New Mexico, Montana, Idaho, Utah, Colorado, Arizona, Oklahoma, Arkansas, Texas, and Louisiana.

## Hardware

Users are introduced to the PLATO system hardware through a terminal. The basic system includes a cathode-ray tube (CRT) display with a touch-sensitive panel, a typewriter-like keyboard, and associated electronics. Two memory banks within the terminal provide a 252-character repertoire. This memory could contain the Greek or Russian alphabets, mathematical symbols, or any other user definable characters. The touch panel, located on the front of the CRT, permits the panel to act as an input device. The user enters data by touching any of the 256 areas of the display screen.

Every key press of the PLATO terminal passes through the entire system, including the central computer. This feature allows for redefinition of the keyboard. Pressing an "m" key is not restricted to producing an "m" on the screen, but may display a line drawing or other appropriate character.

PLATO is powered by a CDC Cyber-170 or similarly capable computer. The system includes extended core storage, disk storage, unique communications equipment, NOS time-sharing operating system, and the terminals. A typical installation consists of peripheral processing units, multiple input-output channels, and a line printer. System storage includes tape drives and the disk mass-storage facilities. Disk storage is used for storing lessons not in use while active lessons are stored in extended core storage. This storage system eliminates expensive, time-consuming program swapping between the

computer and mass storage. It also makes data transfer much faster and access time about 1000 times faster than systems using disks or a drum. Consequently, with hundreds of terminal users linked to the same mainframe, each enjoys a fractional-second response. The architectures of these components combine to provide an educational system where users effectively communicate with the computer and other users.

## Software (Courseware)

PLATO courseware development has produced a broad variety of lesson topics. Many lessons were written by college professors to supplement the courses they were teaching. Some industrial users have developed courses in aviation training, power transmission, and nuclear power plant operation. The Laboratory's E Division uses the system to provide continuing education in electronics, computer science, and management training for their employees. Courses in the use and programming of PLATO are also offered on the system, as are courses specifically designed for women and minorities.

Scientific courses range from astronomy through chemistry and physics to veterinary medicine. Table I indicates the number of Scientific lessons available as of January 1980 and these numbers grow each week. In the past year, 158 new lessons were added to the system; of these the majority are technical lessons. The complexity and availability of a large computer permits very intricate simulations that are limited only by the creativity of the author. Many lessons are introductory in nature, while some are simulations that demand a thorough understanding of the subject matter. A few of the simulations now on line include: A Model Planetarium, An Intel 8080 Simulator, An HP-25 Simulator, and Simulated Patient Encounter. This pedagogical technique yields excellent results and is rated very highly by students using the system.

TABLE I

PLATO SCIENTIFIC LESSONS
(January 1980)

| Scientific Discipline | Number of PLATO Lessons |
|---|---|
| Astronomy | 5 |
| Biology | 12 |
| Chemistry | 105 |
| Computer Science | 56 |
| Engineering | 4 |
| Mathematics | 124 |
| Medicine | 49 |
| Physics | 84 |
| Statistics | 23 |
| Veterinary Medicine | 9 |

Customers purchasing PLATO services may simply use existing system resources or may elect to author a program on their own file space. TUTOR, the author language, is the vital communication link between the lesson author,

the student, the instructor, and the central computer. TUTOR is a relatively simple language, specifically designed for use by noncomputer-oriented authors. The structure of TUTOR provides the necessary protection against unauthorized use or editing of lessons and courses. Complete author identification, password, and access code are essential to use this subsystem. Modes of instruction available with TUTOR include: drill and practice, tutorial, simulation, gaming, and problem solving. Lesson authors can specify a wide range of criteria for acceptable and unacceptable student answers.

Branching allows deviation from the normal lesson sequence to fit individual needs. Students may request additional information by pressing a "help" key or may review previously studied materials by pressing the "back" key. The branching may be initiated by careful programming. This branching capability enables an author to route the student back for a review if the student response indicates poor understanding. Also, students may be allowed to leapfrog ahead in lesson mudules based on correct responses.

On-line aids assist authors in the programming process. Terminal communication capabilities allow authors to contact CDC consultants and to receive assistance with unique programming problems. During such terminal communications an author can permit the consultant to monitor his screen so both parties view identical displays.

Authors at the Laboratory have developed the educational material and contracted CDC to do the actual programming. Testing for an existing electronics videotaped course was programmed on PLATO. Users now receive pretests and posttests for each module in the electronics sequence. If Laboratory courseware development expertise is not available, CDC has a cadre of development specialists to assist in designing and programming courses. The growth and excitement about PLATO has enabled E Division to train a programmer in the TUTOR language. In the future, E Division will complete all aspects of placing a course on the system.

## E-Division PLATO Program

E Division has selected PLATO to integrate many of their educational resources into meaningful, accountable continuing education programs. Of primary importance is the electronics training available through PLATO. The first phase of the electronics program is an assessment examination that covers introductory ac-dc theory through computer maintenance techniques. Table II shows the topics tested in each phase of the electronics assessment examination. You may select the test topics from either Phase I or Phase II in any order you like. An average student completes this assessment in approximately 16 h. Criterion referenced to specific objectives, the test indicates weakenesses to students. The system then prescribes a variety of learning resources to assist the student in overcoming these weaknesses.

The E-Division video viewing facility that houses many videotapes on electronic subjects is a unique resource. PLATO supplies coordination of these taped courses by pretests and posttests on individual tapes. Also, students may view a tape and use the computer resources for drill and practice, problem solving, or simulations on the same subject. Computer-aided instruction establishes accountability because in order to proceed through a lesson the student must interact by correctly answering questions.

The electronics courses are arranged in three curricula: Basic Electronics (Table III); Basic Electricity and DC Circuits (Table IV); and Microprocessors (Table V). Basic Electronics is a CDC product that complements the electronics assessment. Basic Electricity and DC Circuits is a Texas Instruments videotape and textbook course; we developed pretests and posttests for each module and programmed these tests on PLATO for this course. The microprocessor course is available through library B.

TABLE II

TOPICS TESTED IN ELECTRONICS ASSESSMENT EXAMINATION

Phase I

Basic Atomic Theory
Circuit Components
AC Circuits
DC Circuits
AC Circuits
Reactive Circuits
Diodes
Semiconductor Theory
Basic Power Supplies
Mechanical Theory
Oscillators
Amplifiers
Magnetism

Phase II

AND, OR, NAND, NOR Circuits
Symbology
Flip-flops
Counters
Registers
Numbering Systems
Basic Oscilloscopes
Test Equipment
Integrated Circuits
Boolean Algebra
Waveform Analysis
Discriminators and Detectors
Transmission Lines
Troubleshooting
Logical Thinking

TABLE III

BASIC ELECTRONICS COURSES

Introduction to Electronics
Direct Current
Introduction to AC
Tools and Devices
AC Circuits
Circuit Elements
Semiconductor Principles
Power Supplies
Waveform Generators
Oscilloscope Fundamentals
Number Systems
Logic Symbology
Computer Components 1
Computer Components 2

TABLE IV

BASIC ELECTRICITY AND DC CIRCUITS

Electricity Intro
V,I,R
Scientific Math
Ohm's Law
Series Circuits
Parallel Circuits
Parallel Circuit Analysis
Parallel-Series C
Parallel-Series C
Voltage Dividers
Kirchoff's Laws
DC Analysis
Capacitors and RC
Inductance

TABLE V

MICROPROCESSOR COURSES

| | |
|---|---|
| Introduction | Memory |
| Logic Fundamentals | Interface |
| Microprocessor Introduction | D/A - A/D |
| Microprocessor Fundamentals | Serial/Parallel |
| The Language | Troubleshooting |
| Instruction Flow | Higher Languages |

Each of these courses is supplemented with other learning materials. Many lessons send students from the terminal to complete actual experiments using electronic components and equipment. Students may also be assigned reading or audio-visual programs to be completed before continuing a lesson. This assignment is made by PLATO, based on student responses to the testing. As in most computerized testing, test items are randomly selected from a data bank of questions related to a specific topic.

E Division, as well as other Laboratory divisions, has derived many benefits from PLATO. Management training is available on the system. Table VI shows the management curriculum. This aids scientists and engineers who find themselves promoted to management positions for which they have little or no formal training. Also available are lessons on foreign languages; Chinese, Russian, Spanish, French, and Italian are a few of the languages for which lessons are written.

TABLE VI

MANAGEMENT COURSES

| | |
|---|---|
| Managerial Success | Minority Group Dynamics |
| Time Management | Problem Analysis and Decision Making |
| Resources Management | Better Business Letters |
| Emerging Woman Resource | Management by Objectives |
| Excel | Structuring the Organization |
| EEOAA | Directing Others |

Two computer science curriculums have been put together from lessons and courses on the PLATO system. Computer Science (Table VII) consists of PLATO learning-managed courses. Computer Lessons (Table VIII) is a listing of supplementary and special-topic lessons in the computer field. Examination of the topics in Tables VII and VIII indicates a fairly broad coverage of the computer science discipline. These courses, combined with the electronics and microprocessor courses, provide a wealth of material for E-Division employees.

PLATO is available to all Laboratory employees through the E-Division Information and Training Services office. Since PLATO is active 20 h/day, arrangements are made to allow use of this resource after normal working hours. PLATO users like the privacy of one-on-one instruction by way of the terminal. Students' records are stored in the computer file space. Access to the records is restricted to instructors or other authorized personnel through the use of passwords.

TABLE VII

COMPUTER SCIENCE COURSES

Introduction to Computers and Computer Math
Introduction to Data Processing and Machine Language Programming
Introduction to Data Processing for Managers
Introduction to Business Data Processing Con.
Fundamentals of Systems, COBOL
Data Base Management System Environment
Business Systems Analysis and Design
Introduction to Programming in BASIC
Structured FORTRAN
Cyber 170 Job Processing and NOS JCL

Computer-based education is an extension of some of the best qualities in a teacher. It is consistent, patient, and evaluates student responses immediately. Based on strict criteria, it prescribes individual learning sequences, taking into consideration the varied entry levels of students.

We have found computerized education to be an extremely valuable training tool in the research environment. The busy engineer can access courseware after hours. PLATO can adapt to the individual needs of a wide variety of students. Trainees can demonstrate competence through computerized examination and through "hands-on" experiments. Scientists and engineers are enjoying taking courses on a computer. In Los Alamos, over 275 h of instruction are provided monthly by computer-aided instruction. Six months ago the monthly average was 170 h of instruction and the demand continues to grow.

E Division has had PLATO services since April 1979. Due to this increased demand, current plans are to expand our service to eight terminals in April 1981. Two of the additional terminals will be Micro-PLATO terminals. The Micro-PLATO system consists of a flexible disk drive unit attached to a PLATO terminal, making the delivery system much more portable.

The availability of Micro-PLATO opens new avenues for user accessibility to instruction. Frequently used programs can be stored on high-capacity disks that can be accessed at any time. Tutorial and practice are accomplished through interaction with the disk, and major testing is completed on the PLATO terminal connected to the mainframe. This new flexibility provides lower cost instruction without reducing the effectiveness of the training or the management capability of the system. will be experimenting with Micro-PLATO in the near future.

TABLE VIII

COMPUTER LESSONS

Disk Pack I
Disk Pack II
Compact Basic Compiler System
Flow Chart Introduction to Basic Computer Program
FORTRAN Specifications--A Drill and Practice
FORTRAN Sample Introduction to Computer Programming
Input/Output Words
Intel 8080
Intel 8080 Simulator
Introduction to Computers
Introduction to FORTRAN Subroutine Subprograms
Introduction to APL
Inverters, Gates, and Flip-flops
Overview of Terminals
PPU Architecture
PPU Compass Simulator
PPU--No Address
PPU--Direct Instructions
Sample PPU Compass Program
PPU--Indirect Instruction
PPU Jump Instructions
PPU Constant Instructions
PPU Memory Instructions
PPU LJM/RJM
PPU Central Instructions
Channel Instructions
Data Structures in PL/1
Data Structures/Introduction for PL/1
A Mini Program with Semaphores
A Mini Program Input/Output Supervision
Mini Program Tree and List
Multidimensional Arrays in FORTRAN
PL/1 Arithmetic
PL/1 Arrays
PL/1 Arrays Advanced
PL/1 Do Loops
PL/1 Drills-Input/Output Statements
PL/1 Edit Statements
PL/1 IF Statements
PL/1 Input/Output
PL/1 Introduction to the Sequence
PL/1 Picture Specification
PL/1 Procedures
PL/1 Strings
Recursion in PL/1
Scalar Arithmetic in APL
Structure of a Computer/Machine Language
Vector Arithmetic in APL
Basic 6000 Cyber CPU Introduction
Introduction to Compass
The Increment Unit
Conditional Test and Branching Instr.
Boolean and Shift Units
Integer Data Operations
Return Jump Instruction
Floating Point Data Operations
CPU Compass Simulator
HP-25 Calculator Simulator
Plotting Recursively Defined Curves